FAA Aging Electrical Systems Research Program

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Aging Transport Systems Rulemaking Advisory Committee
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Briefing Topics

- Arc Fault Circuit Breaker Update
- FAA Aging Electrical Systems Research Projects
- Wrap-up / Q&A

Arc Fault Circuit Breaker Update

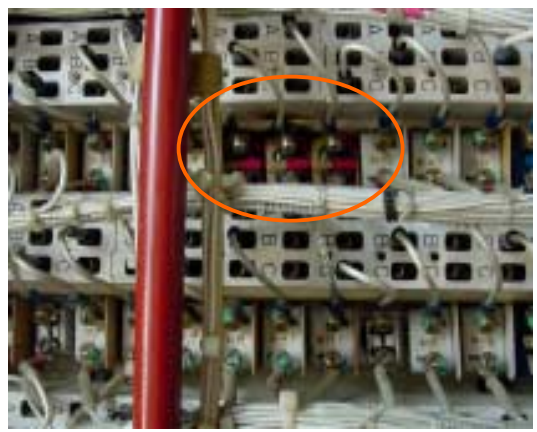
Outline

- AFCB Program Update
- Pros/Cons of AFCB Installation
- AFCB Implementation Considerations
- Present & Future Arc Fault Protection and Diagnostics Options

AFCB Program Status

- Eaton Corporation
  - 20 units delivered for flight testing on FAA Boeing 727 and Navy Boeing C-9
  - Navy flight testing began 24 August, 2001
  - FAA flight testing began 10 September, 2001
- Hendry Telephone Company/Texas Instruments
  - Safety of flight laboratory tests February 2002
  - Flight test in April 2002

AFCB Installation on
Navy C-9 Aircraft (VR-56)



First Navy Flight of Eaton AFCB on August 24, 2001

AFCB Installation on FAA B727 (N40)

Data Recording

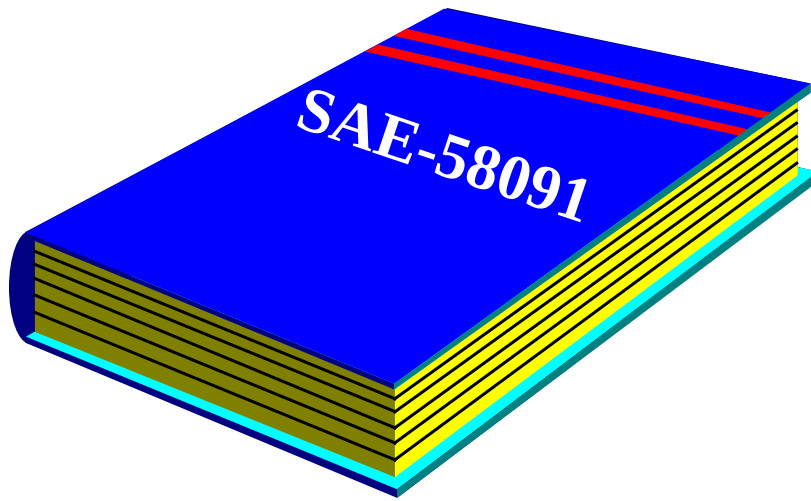
Eaton AFCB's

R&D Flight Test Status

- FAA B727 Flight Test Hours
  - **28 Flight hours**
  - **200 circuit breaker hours**
- NAVAIR C-9 Flight Test Hours
  - **190 flight hours**
  - **1143 circuit breaker hours**
- Total Flight Test Hours
  - **218 flight hours**
  - **1343 circuit breaker hours**
- Hours do not include ground operating time.

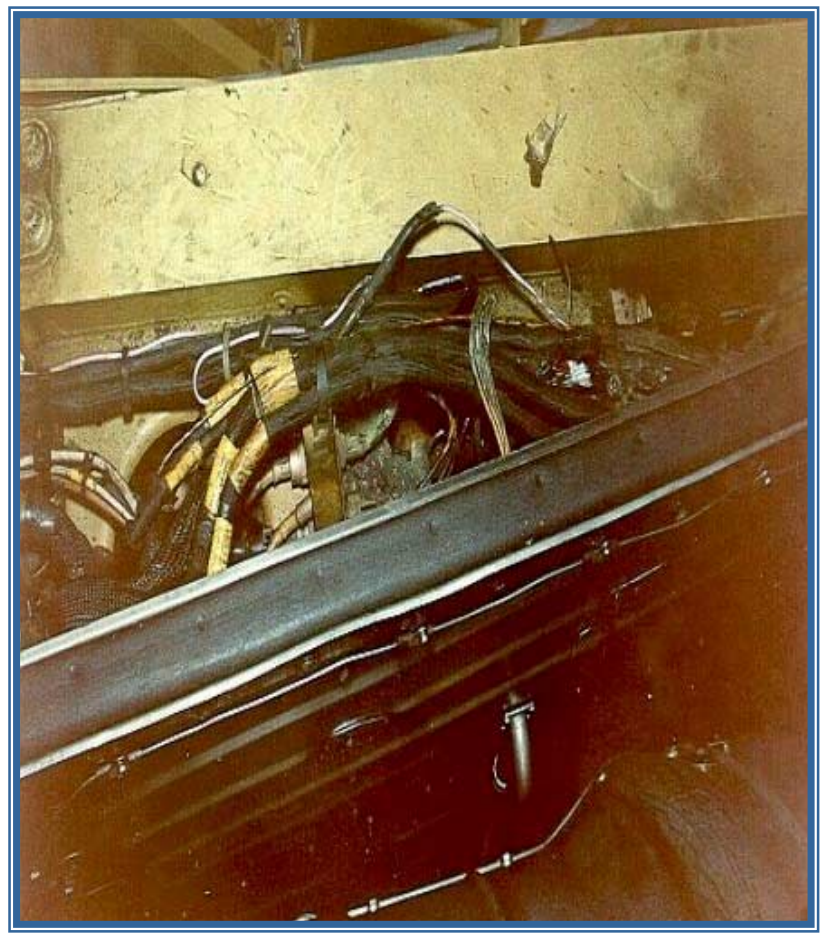
SAE-8B1 AFCB Specification

- Society of Automotive Engineers Aeronautical Division
  - Protective Device committee (SAE-AE8B1)
  - Updating SAE 58091 (Formerly MIL-C-5809) Circuit Breaker Specification for Thermal and Arc fault protection
  - Preliminary Spec Available September 2001
  - Finalized January 2002



Pro's of Installing AFCB's into Circuits

- Prevents catastrophic damage to wiring system
- Reduce arc energy for starting fires
- Identifies circuits on which arc faults are occurring
- Actively monitors circuits



Con's of Installing AFCB's into Circuits

- Determining Overload vs. Arc Fault vs. Nuisance Trip
- Assurance of AFCB Functionality
- Additional wire maintenance due to potential increases in trip rates from interconnect system degradation
- Post trip troubleshooting, determining location of arc fault

Implementing Considerations/Approaches

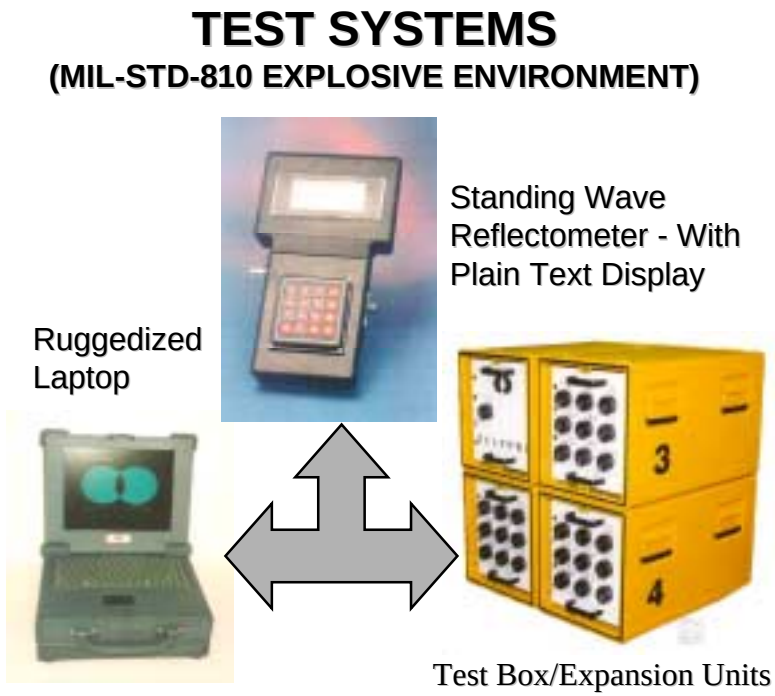
- Fire and Smoke Incident Data
- Maintenance Data
- Reliability Data
- Risk Analysis
- Wiring Zones
  - SWAMP
  - Environmental Conditions
  - High Maintenance Areas
    - Avionics bay
    - Passenger Cabins
    - Cargo compartments

Implementing Considerations/Approaches

- Connected Equipment
  - Non-Flight Critical Equipment
    - Passenger/cargo
  - Flight Critical With Redundancy
  - Emergency Flight Loads
  - Risk Analysis
    - Functional/Physical
    - Intra-system hazards

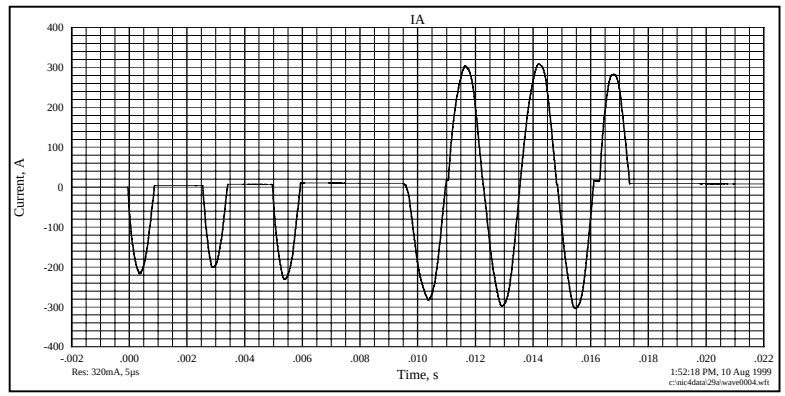
Trouble Shooting Arcs

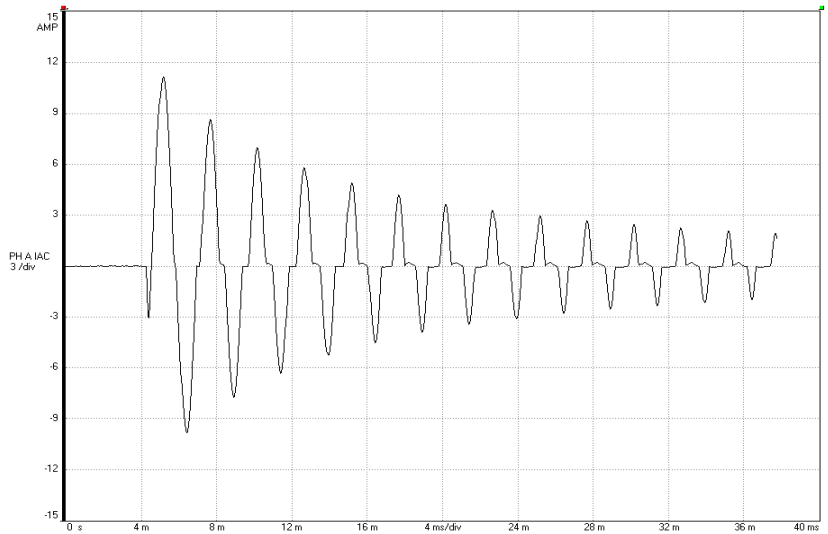
- Off Board Aircraft Wiring Tester
  - VOM
  - TDR/FDR/SWR
- On-board Wiring Diagnostics
  - Smart Wire



Preventing Nuisance Trips

- Determining arc fault detection circuitry health
  - Off Board Tester
  - Internal AFCB Tester
  - Equipment Operation
- Qualification testing
- Load compatibility tests





Future Arc Fault Protection

- Miniaturized single-phase AFCB
- 28 Volt DC AFCB
- Three-Phase AFCB
- Contactors
- Generator Control Units

Advanced Diagnostic and Protection Features

- Diagnostics
  - AFCB Operational Test
    - Internal Built in Test (BIT) vs. External tester
  - Arc Fault Locator
    - Internal versus external
- Circuit breaker communications
- Wire Protection
  - Coordination
    - Arc fault and thermal trip coordination
  - Multiple Protection Devices
    - AFCB, motor contactors, Bus tie contactors, generator control units

Wire Degradation Research
Phase II

Wire Degradation Research

- Raytheon Technical Services selected to conduct the program.
- Kick-off meeting completed. Tasking and scheduling completed.
- Working partners established
  - Sandia National Labs
  - Brookhaven National Labs
  - Lectromec Corporation
- Formulation of test protocols and design of experiments

Wire Degradation Research

- Survey Stakeholders - Formulation of test protocols and design of experiments – need stakeholder participation
  - OEMs
  - Wire & Materials Processors/Manufacturers
  - Airline maintenance/engineering
  - Military representatives
  - Other industry/academic experts
- See Joe Kurek, Raytheon, 317-306-7029

Aging Circuit Breaker Testing

Aging Circuit Breaker Testing

Twelve panels from two aircraft

- Process 1 testing complete
  - 200% & 500% overload
  - 60 Breakers
  - 4 Test Failures
    - One breaker would not close
    - Two breakers tripped prematurely on 200% test
    - One breaker tripped immediately on 200% test

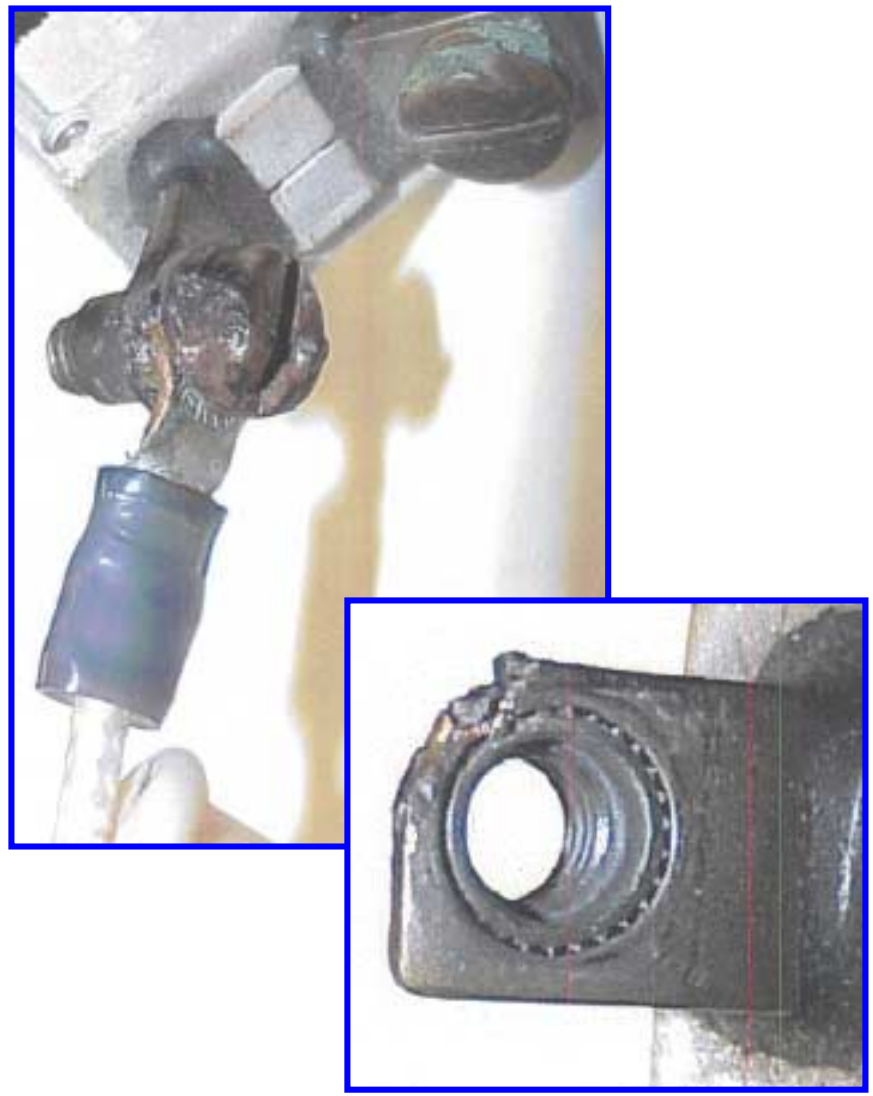
Aging Circuit Breaker Testing

Loose Terminal Post Screw
Numerous Occurrences
Also:
Inconsistent application of screws and washers

Blackened Sleeve
High Temperature
Also:
Multiple circuits terminated to same breaker

Aging Circuit Breaker Testing

Evidence of arcing or high temperature connection



Aging Circuit Breaker Testing

Process 2 testing initiated

- Full MIL-C-5809 test regimen
- 240 Breakers
- X-Ray
- Failure analysis
- Final report – March 2002

Aging Electrical Component Testing

Purpose:

- Perform appropriate testing on aged electrical interconnect system components and assess performance and potential age related affects.

Scope

- Relays, RCCB’s, switches, contactors, etc.
- Similar to aging circuit breaker testing

Advanced Risk Assessment Methods for Aircraft Electrical Systems

Advanced Risk Assessment Methods for Aircraft Electrical Systems

Develop advanced EIS risk assessment tools.

- Accidents and incidents that have occurred in the past indicate the current tools used in the development and assessment of EIS during the design process and during EIS modifications may not identify all potential failure modes.

Advanced Risk Assessment Methods for Aircraft Electrical Systems

- Severity of a failure is related to both the loss of functionality as well as the potential for fire or other physical damage to the aircraft
- Intra-system hazards
- Systems Engineering
  - Analysis of system level trades
  - Optimization

Advanced Risk Assessment Methods for Aircraft Electrical Systems

- Three-year program
- Four final proposals are under review – contract award in near future.
- Methods will be:
  - Relevant – must be firmly fixed in the real world.
  - Practical for aviation community.
  - Useful – do more than point out the obvious.

Advanced Risk Assessment Methods for Aircraft Electrical Systems

- Phase 1 – Identify current risk assessment methods from aviation community and other high consequence systems.
- Phase 2 – Develop advanced risk assessment methods.
- Phase 3 – Develop supporting software, process infrastructure.
- Phase 4 – Aviation community evaluation.

Evaluation of Wire Separation & Segregation Requirements

Evaluation of Wire Separation & Segregation Requirements

- Review current regulations, best practices, incident/accident data, and other relevant guidance and materials.
- Assess current requirements. Identify strengths of current requirements and propose improved and/or new requirements where weaknesses are identified.
- Systems approach. Intra-system hazard potential.
- Functional and physical consideration.

Evaluation of Mixed Wire Types in Aircraft Electrical Systems

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Wire Test & Inspection Technology

Wire Test & Inspection Technology

- CM Technologies – Excited Dielectric Test
- Combination of TDR and Dissipation Factor
- Benefits include:
  - Detect and locate defects which are not visible
  - Non-destructive
  - Wire condition can be determined through a single set of tests (no baseline)
  - Can also determine the condition of other wiring system components (e.g., connectors, splices)

Wire Test & Inspection Technology

- Data collected over the past year suggest that EDT works
  - Single conductor and twisted pair configurations
  - Two types of insulation were studied
    - Polyimide (Kapton™)
    - Cross-linked ETFE (Tefzel™)
  - Subtle insulation defects are easiest to detect when contaminated
- Relative comparisons can be made with different forcing functions
  - No baseline required

Wire Test & Inspection Technology

- Validation work complete by end of year
- Final report March 2002

Wire Test & Inspection Technology

- Boeing/Rockwell Science Center/Eclypse – Broadband Impedance Monitoring
  - Broadband impedance measurements
  - Standing wave reflectometer
  - Degradation modeling
  - 3 year effort

Wire Test & Inspection Technology

- Brookhaven National Laboratory – Terahertz Reflectometry
  - Extremely high frequency
  - Propagate signal through the insulation parallel to the conductor.
  - Range may be limited
  - Three year effort

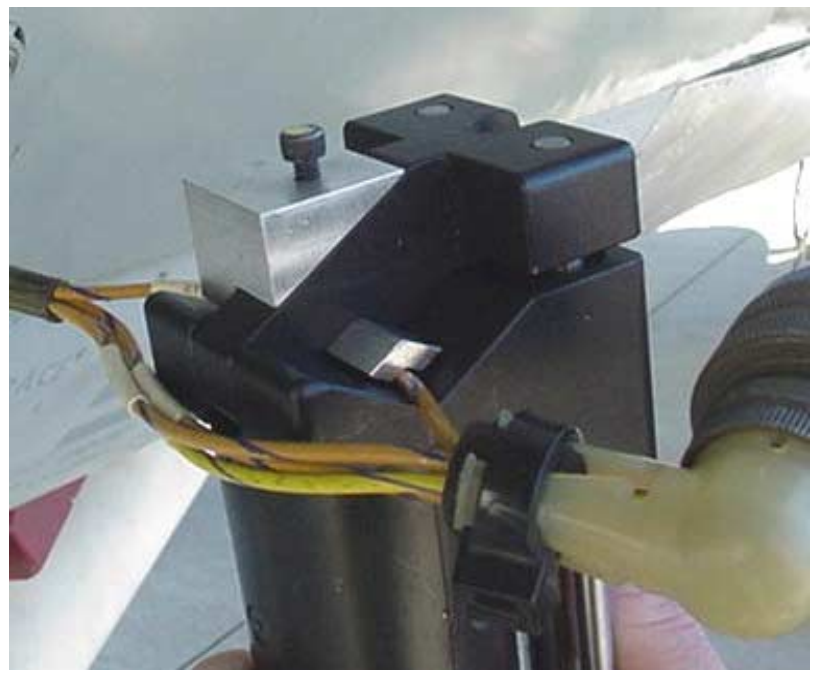
Wire Test & Inspection Technology

- Killdeer Mountain Manufacturing – Wire Chafing Detection Technology
  - Design, fabricate, and test prototype on a high risk assembly
  - Sense shield
  - Risk formulation to direct technology to greatest areas of need
  - Flight test – United Airlines
  - Reflectometry to monitor sense shield condition
  - 12 month effort

Wire Test & Inspection Technology

- Analog Interfaces – Material Testing and Indenter Development

- Modify indenter technology successfully used by the nuclear power industry to monitor insulation condition.
- Hardness modulus measurements
- Material testing of wire samples undergoing accelerated aging



Wire Test & Inspection Technology

- Analog Interfaces – Material Testing and Indenter Development
  - Correlate hardness measurements with established methods such as elongation at break
  - Monitor wire degradation at the macro-level not the defect level
  - Investigate relaxation mode
  - Insulation thickness
  - Construction - tapes
  - 12 month year effort

Wire Test & Inspection Technology

- Other contracts pending award
  - Arc Detection with TDR
  - Smart Connectors (SBIR)
  - Pseudo-random Binary Sequence Reflectometry (SBIR)
  - Neural Net Automated FDR Chafing Detection (SBIR)
- FY-02 BAA for Wire Test & Inspection Technology

Instrusive Inspection - Commuters

- Currently establishing requirements within FAA
- Will be modeled along the transport program
- ATSRAC assistance
- Development of inspection protocol
- Complete inspections
- Issue report

Development of Electrical Systems Validation Testbed

- Required to validate inspection technologies against a standard benchmark
- Sandia National Laboratories
  - Structural NDI Validation
  - Polymer expertise
  - Scientific equipment available for post test follow-up

Development of Electrical Systems Validation Testbed

- Phase 1
  - Requirements definition
  - Aircraft wiring samples
  - Generic test fixtures
- Phase 2
  - Add diverse wiring sample sets and defects
- Phase 3
  - Testbed refinement
  - Exploration of wiring inspection and maintenance practices

Other Projects in FY-02

- Evaluation of mixed wire types
- Maintenance effects on electrical interconnect system
- Wire Separation/Segregation Requirements